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A LOWER BODY NEGATIVE PRESSURE BOX FOR +GZ SIMULATION IN THE UP--ETC(U)
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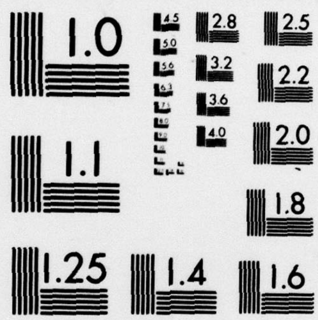

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16. Abstract

The cost of purchasing and operating a human centrifuge is substantial. Lower body negative pressure (LBNP) is considered an acceptable experimental substitute for the +Gz stress of the centrifuge. Since civil aviation pilots are usually subjected to +Gz stress in an upright seated position, an upright seated version of the supine LBNP box was developed. In this version, a negative pressure of -40 mm Hg is considered the equivalent of a +2 Gz stress. This box has successfully withstood a test pressure of -120 mm Hg. Pedal ergometry within the box is easily accomplished. The box was anthropometrically engineered to accommodate a human height range of 160-195 cm. Locating the box within an altitude chamber allows the application of LBNP at any level of chamber altitude. The total cost of fabrication is approximately $500.

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A LOWER BODY NEGATIVE PRESSURE BOX FOR +Gz SIMULATION IN THE UPRIGHT SEATED POSITION

Introduction.

The necessity to assess the effects of zero-G space flight on the +Gz tolerances of astronauts led to the development of the lower body negative pressure (LBNP) box (5). In terms of construction cost, size, and operational complexity, this simple means of simulating a +Gz stress by shifting blood volume to the lower half of the body is much more advantageous than the use of a human centrifuge. As reviewed recently (3), the supine version of the LBNP box has been used in several types of experimental studies.

Although supine application of LBNP retains many useful experimental purposes, the upright seated position of the civil aviation pilot in flight has led to the development of an LBNP box which applies the same simulated +Gz stress in the upright seated position. Because our previously standardized pedal ergometry was also applied in the upright seated position (1), it was logical to combine both equipment setups into one by installing a pedal ergometer within our LBNP box. This allowed the ergometry and +Gz testing to be run sequentially without dislocation of the subjects from one equipment setup to another. With this unified setup, if desired, the option of simultaneous application of ergometry and +Gz testing is also afforded. Since our LBNP box was easily accommodated within our altitude chambers, the ergometry or LBNP testing could be applied at ground level or at altitude. This device was tested successfully and has since been adopted as a standard method in our aeromedical research for testing +Gz and ergometric tolerances at simulated chamber altitudes up to 3,810 m MSL (2). For those who may desire to construct and use this version of the LBNP box, this paper provides a physical description of the device and its salient operational characteristics.

Physical Description.

Figures 1 and 2 present side and internal views of our LBNP box. Figure 3 depicts the hatch cover and its adjustable waist-surrounding iris system. The internal dimensions of the box are: maximum height = 98.5 cm, maximum height at rear of seat = 53.3 cm, width = 59.7 cm, floor length = 154.9 cm, length at 53.3-cm-height level = 179.1 cm, and length of top = 54.6 cm. The plexiglass access door is 53.3 cm wide, 58.4 cm long, and 1.3 cm thick. The empty internal volume of this box is approximately 0.81 m^3. This is approximately twice the empty volume of the supine LBNP box (5). The back and floor consist of 2.5-cm-thick plywood, and the sides, front, top, hatch cover, and seat-cushion support consist of 1.9-cm-thick plywood. Internal cross braces of lumber were located at anticipated points of maximum stress. The external metal brace seen in Figure 1 is a redundant reinforcement. The box is mounted on four 10.2-cm casters for easy mobility. Although this box is routinely used at a negative pressure of -40 mm Hg, it has withstood a test pressure of -120 mm Hg.

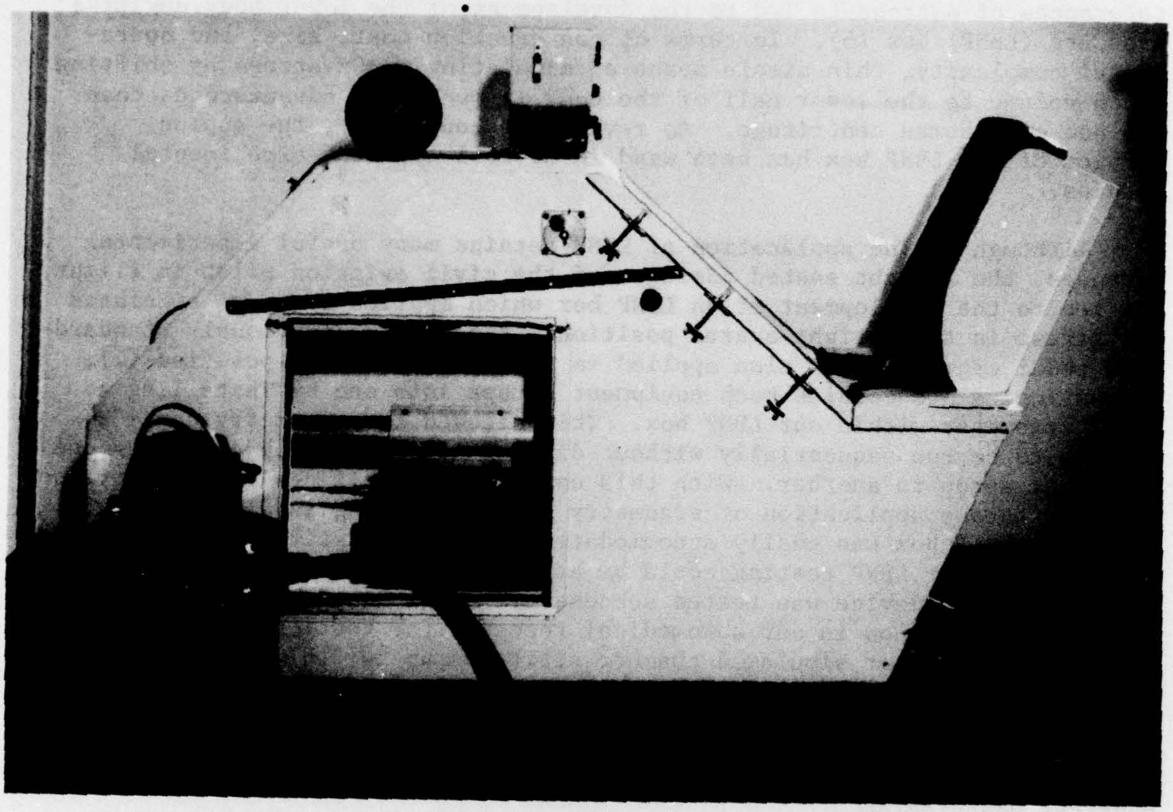

FIGURE 1. Side view of the upright seated LBNP box.

The back support is angled at 125° from the horizontal plane. The seat-cushion support board is 50.8 cm wide, 59.7 cm long, and its front edge is angled upward at 5° from the horizontal plane. These seat and back angles were determined anthropometrically for maximizing seated comfort and for minimizing "kinking" of the femoral artery during pedal ergometry. The seat and back cushions consist of 10.2-cm-thick foam rubber with polyvinyl covers. The seat board is supported at each of its four corners by a notched metal stanchion. The four stanchions are notched at 2.5-cm intervals to accommodate individuals of different heights.

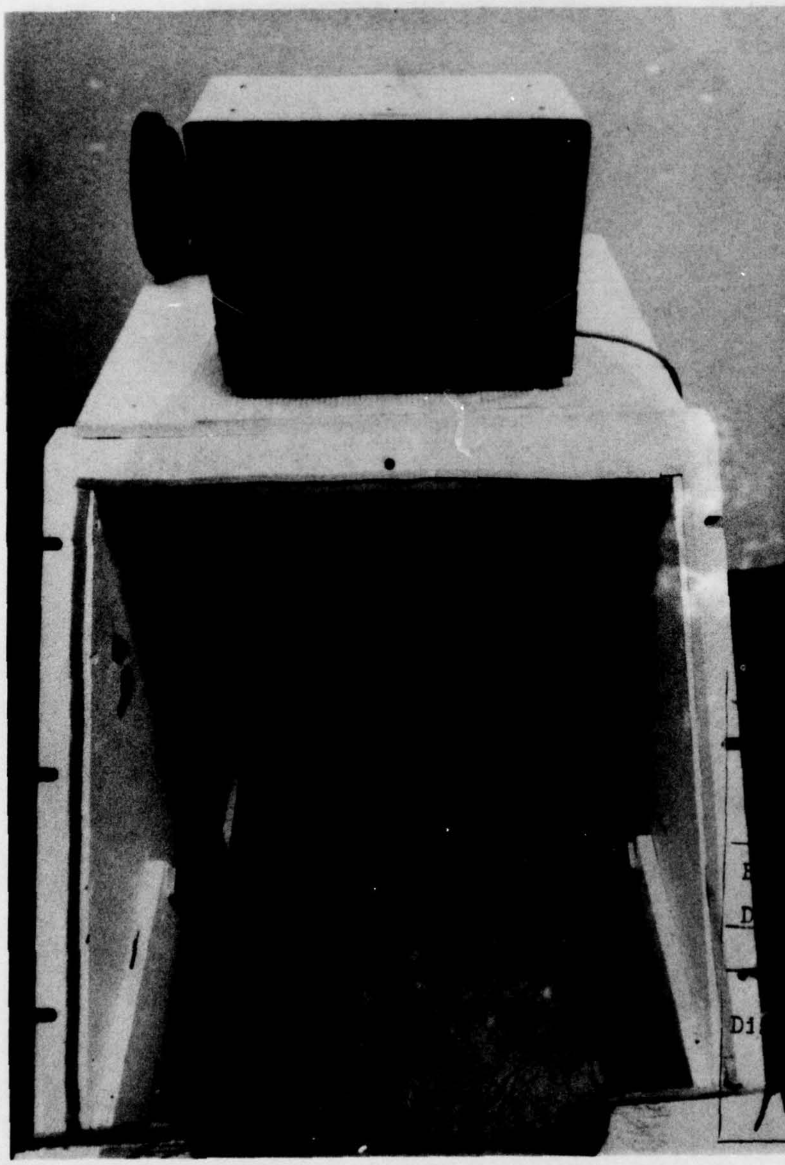

FIGURE 2. Internal view of the upright seated LBNP box.

The hatch cover (Figure 3) is 69.9 cm wide, and 66.7 cm long with a waist-front opening of 40.6 cm wide, and 26.7 cm long. The padded semicircular waist-back opening (Figure 3) is 40.6 cm wide and 10.8 cm deep. The three adjustable waist-contoured slats (Figure 3) and the sheet-rubber waist

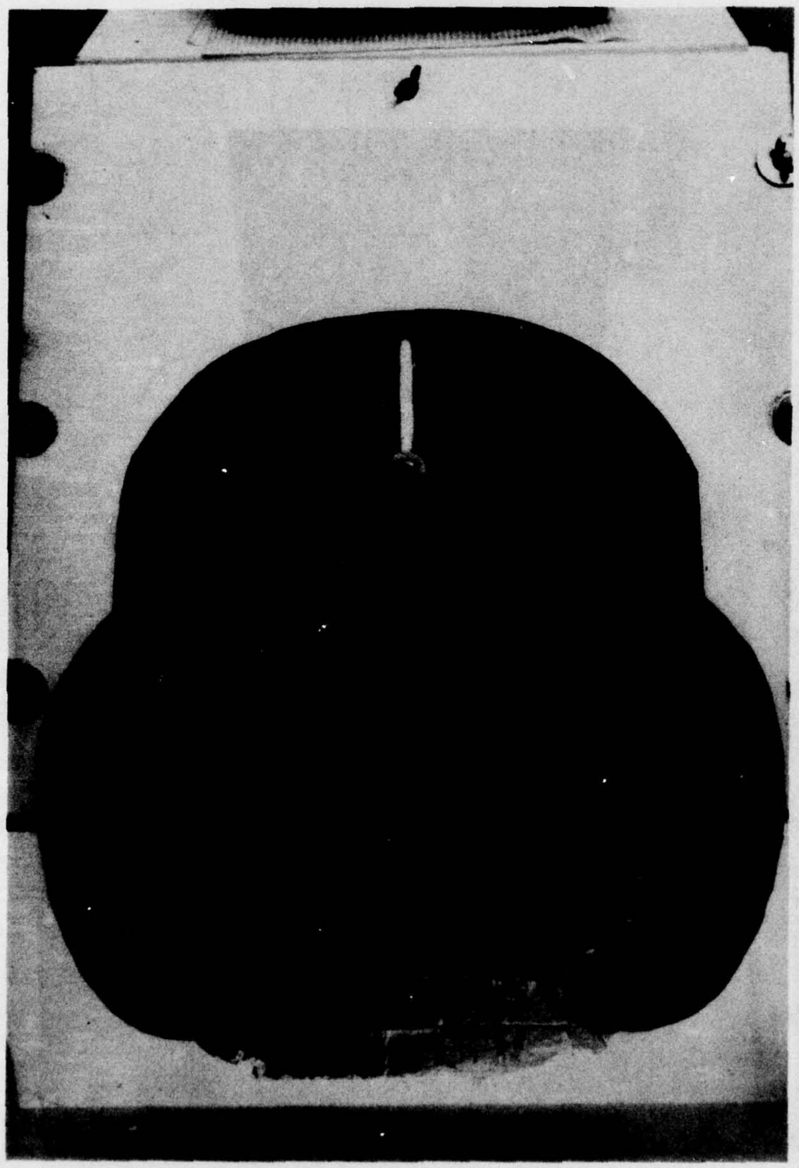

FIGURE 3. External view of the hatch cover and its three adjustable waist-contoured slats.

seals are similar to those reported previously by others for use with the supine LBNP box (6). The hatch-cover port is angled upward at 43° from the horizontal plane. This anthropometrically determined angle was the minimum allowable value for frontal waist-sealing without compromising thoracic ventilatory excursions, and for pedal ergometry without the knees bumping into the hatch cover. This angle and the adjustment ranges of seating height and pedal length were anthropometrically determined to accommodate a subject height range of 160-195 cm.

A 0.75-horsepower vacuum cleaner (Figure 1) is ordinarily used as the source of negative pressure. When our LBNP box is used at substantial chamber altitudes, the negative pressure source is the vacuum-accumulator tank of the altitude chamber. The level of negative pressure inside the box is regulated by an adjustable orifice located in the upper-left sidewall, and the pressure magnitude is continuously indicated by a mercury-calibrated differential pressure gauge connected to the inside of the box (Figure 1).

The pedal ergometer (Figures 1 and 2) (Pedalmate, Warren E. Collins, Inc., Braintree, MA) is mounted on an adjustable locking slide track to accommodate interindividual variability in leg lengths. The adjustment for leg length is made via the plexiglass access door. The ergometer console for controlling load and revolutions per minute is located on the top of the LBNP box (Figure 2).

Operation.

For our experimental purposes, the LBNP box is located inside one of our altitude chambers. Thus, it can be used at ground level or at any desired chamber altitude. Initially, the subject is seated in the box for determination of the maximum seat height which still includes the iliac crest within the box, and the optimum pedal distance for comfortable ergometry. The subject then exits the box and is fitted with all the sensors to be used during the experiment. The sheet-rubber waist seals are tied circumferentially in place, and the subject is reseated in the box. The hatch cover is positioned and bolted in place. The three contoured slats are adjusted to the individual's waist size, and the rubber waist seals are superimposed upon them. The generation of negative pressure within the box causes the waist seals to be pulled toward the waist/slats junction and thereby produces a seal of sufficient degree to maintain the desired level of LBNP.

In terms of blood volume and heart rate displacements (4,5), a negative pressure of -50 mm Hg in the supine LBNP box is considered to be equivalent to a +2 Gz stress. Based on our measurements of heart rate, a -50-mm-Hg pressure in the supine LBNP box is equivalent to -40 mm Hg in the upright seated LBNP box. At a chamber altitude of 3,810 m MSL, we have standardized our LBNP test at -40 mm Hg for a duration of 2 min. Variables usually assessed during this LBNP test are: single-lead electrocardiogram, heart rate, auscultative blood pressure, earoximetric arterial oxyhemoglobin saturation, temporal artery blood flow velocity (Doppler), tidal volume, and respiratory frequency (2). When experimentally desirable, psychomotor tests of the manual speed and coordination types are quite easily applied to the subject while seated in the LBNP box.

Exclusive of the pedal ergometer and the vacuum cleaner, our LBNP box can be fabricated for a combined labor and materials cost of approximately \$500. This inexpensive device should provide access to seated +Gz studies by any investigator who cannot afford the cost of acquiring or operating a human centrifuge.

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